Re-using microwave oven transformers for high-voltage power supplies

Drew Diamond VK3XU

One of the difficulties for the linear amplifier builder is in obtaining high-voltage power transformer(s). A popular requirement for (say) a 1.3 kV plate supply is a transformer with a secondary voltage of typically 1 kV RMS at perhaps 500 mA or 1 A. A costly item, even second-hand, and as a made-to-order part? It hardly bears thinking about.

> ***WARNING.***
>
> ***Voltages in equipment in this article are lethal. This article is only for experienced operators. Rigorous attention to safety is mandatory.***
>
> ***Particular attention should include making sure that contact with this equipment during operation is impossible, even by accident such as bumping and fainting. A second person as a safety observer who can disconnect the power and call for help is recommended.***
>
> **Technical Editor.**

A few resourceful enthusiasts have had some success with transformers rescued from defunct microwave ovens. They certainly look attractive to the handy amateur. Let me list some of their features: cheap (usually zero cost), well-made to high electrical and mechanical standards, core/primary rating of about 400 ~ 500 VA, re-workable for low and high-voltage PSUs, large volts-per-turn, crude voltage regulation provided (by running in saturation mode), and quiet operation (due to welded laminated core).

Their disadvantages are: increasingly poor efficiency when operated above about 200 V AC primary voltage (and therefore runs very hot if powered continuously), secondary HV winding connected to core (easily altered - see later), and the welded core makes disassembly impossible.

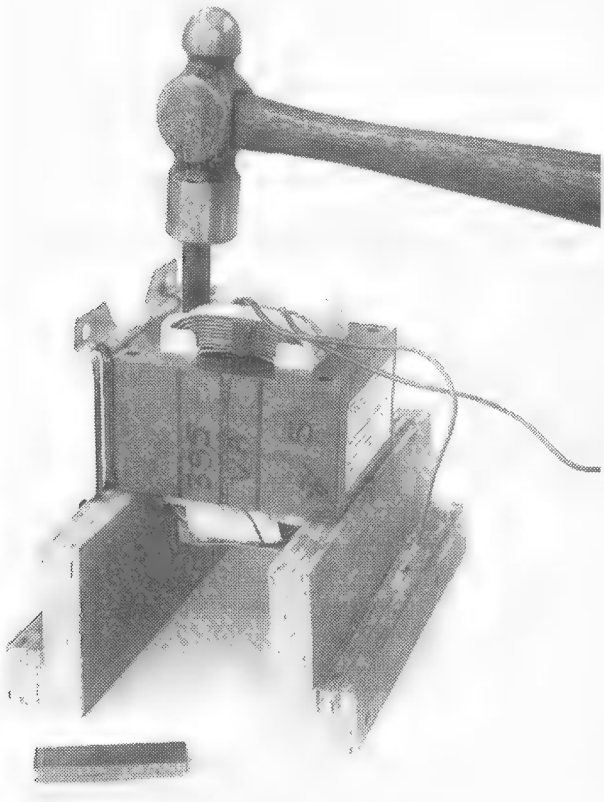


Photo 1 - Removing magnetic shunts.

In its usual application, the transformer runs in 'saturation' mode, where the primary magnetizing current is quite large (typically 1.5 A). This, together with the magnetic shunts fitted to the core, provides a degree of output DC voltage regulation, and so allows for a wide range of loads upon the 2 kV secondary winding that powers the magnetron oscillator (Reference 1). Intermittent domestic use normally provides prolonged cooling-off periods for the transformer, so a much smaller core may be employed. To prevent damage, however, a number of thermal cut-outs are fitted to vital components within the appliance (Reference 1).

The estimated number of turns found on the typical "rescued" transformer primary is about 240, which is one volt per turn - a very high figure. If one makes some reasonable assumptions about the core flux density; application of the usual winding formula (References 2 and 3) confirms that the primary is actually better suited to 120 V AC, giving (usually) 0.5 volts-per-turn.

A solution is to run two identical or similar transformers with their primary windings in series (120 V AC across each primary) from a 240 V AC supply. Magnetising current is then only about 180 mA. Their secondary windings may now be connected in parallel to give 1 kV AC (about 1.3 kV DC), or in series to produce 2 kV AC (about 2.6 kV DC) for "voltage-hungry" tubes like 4-125s or 813s. We thus have two 400 VA transformers, loafing along, each capable of delivering its rated VA continuously.

Method

Before I go further, let me state the following warning: Tests upon, and modifications to, mains transformers, as described here, must only be done by suitably experienced and/or qualified persons. ***There is a real danger of ELECTROCUTION should skin contact occur.***

Here are some essential rules:

- ***Keep hands off when mains voltage is applied. Do not rely upon the insulation of multimeter test prods and leads.***

Therefore

- ***Connect your meter using suitable connectors, and then adopt a strict "hands off" attitude whenever mains is applied.***
- ***Always earth the cores to mains ground.***
- ***Never leave a test set-up unattended by you. Disconnect and remove the mains lead when each work session is completed.***

Find two or more discarded ovens (they should be heavy - newer ovens use switch-mode power supplies) of similar power rating. Upon disassembly, save the spade connecting wires, particularly the valuable HV wires that connect the diode, magnetron and capacitor assemblies.

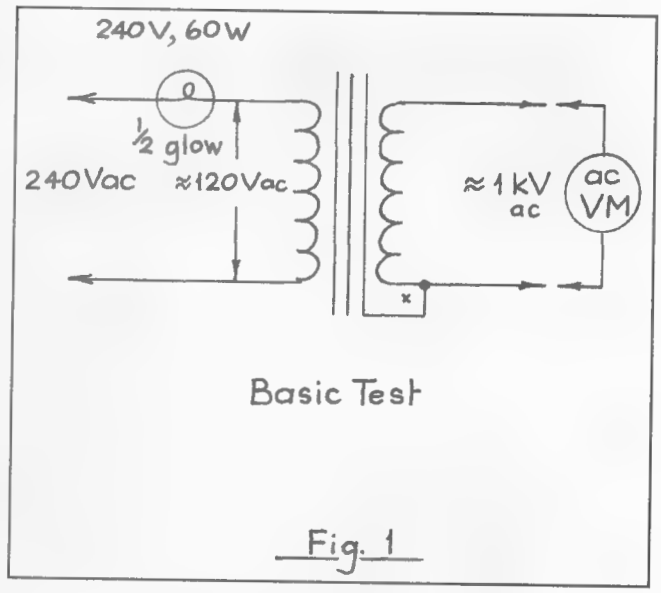
With a multimeter on ohms x1, measure the resistance of the primary winding, which should be about 1.5 ohms. The secondary winding is measured between the mounting plate and the single spade lug. A slow reading of about 60 ohms to 90 ohms should be obtained. If there are no "brown" smells, the transformer is probably serviceable.

The transformers must be fairly well matched for VA rating. Measure the winding-limb area, shown marked upon the core in Photo 1. VA may be calculated:

$VA = (5.58 \times L \times W)^2$ (References 2 and 3) where L and W are in inches, ***or***

$VA = (0.00865 \times L \times W)^2$ where L and W are in mm.

To test a transformer, you will need a multimeter capable of measuring to 2.5 kV AC (such as an AVO Model 8). Wire a mains lead to a 240 V 60 W lamp connected in series with the primary winding, as shown in Figure 1. All connections MUST be insulated. Apply mains power. The lamp should only light to about half brilliance, indicating that the transformer is probably good.



Carefully measure the voltage across the reactance of the primary winding, which should be about 120 ~140 V ac. Remove power, then connect your meter, set to 2.5 kV fsd across the HV winding. Apply power again. You should obtain about 1 to 1.3 kV ac across the secondary. If your two transformers give similar voltage readings, and their core VA ratings are the same or similar, then it is quite practicable to connect them as described later.

For amateur applications that require a well-regulated, low-ripple HV supply, it is impracticable to use a secondary that has one side grounded to the core (and don't even think about 'floating' to core). In most instances the coil wire may be carefully 'lifted' from the ground lug, so that the winding is isolated. Extensive tests upon a number of transformers have shown that the quality of insulation normally fitted is easily capable of withstanding 2 kV AC RMS between winding inner and core.

The aforementioned magnetic shunts should be removed. Place the transformer upon two pieces of timber then, using a suitably sized length of steel or brass, drive the two shunts out of the core, as depicted in Photo 1. One thus removed shunt may be seen in the foreground. The 'flying' leads are those of the 3.3 V heater winding. They may be simply clipped, leaving the winding intact, or the (usually) three turns may be unwound from the core, as desired.

Photo 2 shows a typical modification, where the ground connection has been severed, and a new length of high-voltage wire soldered to the enamelled wire where it emerges from the coil. Use a cable-tie, or similar, looped

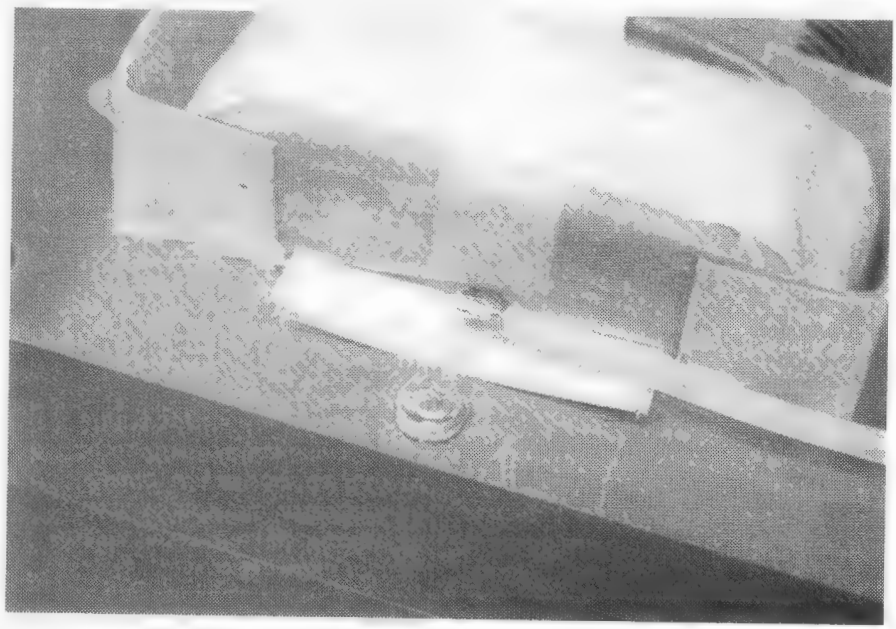


Photo 2 - New HV wire connected.

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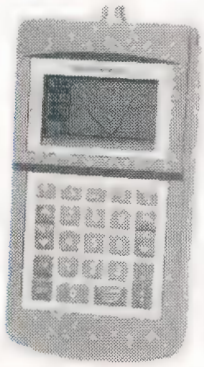

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around the winding, where necessary, to anchor the new wire. The connection, and the area around the wire's exit, must be covered with a layer of acid-free silicone, as pictured in Photo 3.

Fabricate a rectangle of Bakelite, phenolic, or similar insulating material such that it spans two of the core mounting holes. Fit two well spaced (from each other, and ground) screw terminals and/or spade connectors to suit your planned project. The insulator may be mounted upon the transformer using $^{5}/_{32}$" Whitworth or 4 mm all-thread in a manner like that shown on Photo 4.

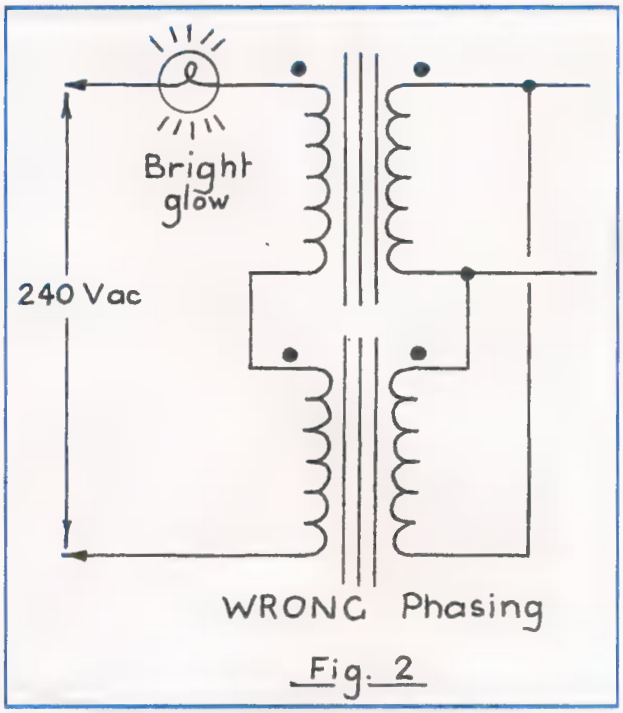

Fig. 2

1 kV AC Secondary

Having thus modified two transformers, it only remains to find the correct 'phasing' of the windings. Wire the primaries in series with your 60 W test lamp, as shown in Figure 2. Arbitrarily connect the secondaries in parallel. Apply mains power. If the lamp is bright, the phasing is wrong. Reverse either the connections to one primary, or those of one secondary, and try again, whereupon the lamp should glow dimly (Figure 3). With the lamp out of circuit, measure the secondary voltage, which should be about 1 to 1.1 kV AC. Each primary should have 120 V AC applied, as shown. Suitably mark your connectors accordingly.

2 kV AC Secondary

The secondaries are connected in series, as shown in Figure 4, such that the formerly grounded sides of each winding, marked 'x', are wired together (thus greatly reducing the stress on the insulation). Arbitrarily wire the primaries in series. Connect your multimeter set for 2.5 kV AC to the whole secondary. Apply mains power. If near zero volts, phasing is wrong - reverse one primary. If 2 to 2.2 kV AC - phasing is correct.

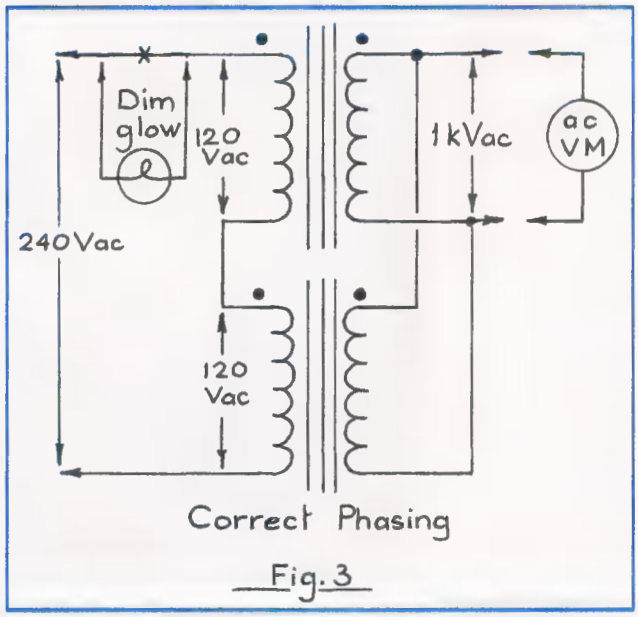

Fig. 3

Rectifier Circuit

An appropriate rectifier/filter rather depends on application. However, for a 1 kV AC primary, a full-wave diode bridge

Photo 3 - Siliconed HV wire connection.

comprising at least 3 x 1 kV PIV/3 A diodes per leg (12 diodes) is suggested. The filter capacitor may comprise 4 x 220 µF/400 or 450 V in series, with a 100 k 3 W metal-film bleeder resistor across each capacitor. No-load output will be about 1,300 V DC. At a load current of 400 mA, voltage will (typically) fall to 1100 V. Double the diode and capacitor numbers for a 2 kV ac secondary. Typical rectifier circuits may be found in References 4, 5 and particularly 6.

Primary Circuit

For either secondary configuration, the primary side should be wired in accordance with Figure 5. Include a 4 A 'slow-blow' fuse in each side of the mains supply. A slow-start circuit was found not to be necessary. All connections must be suitably covered to prevent accidental contact.

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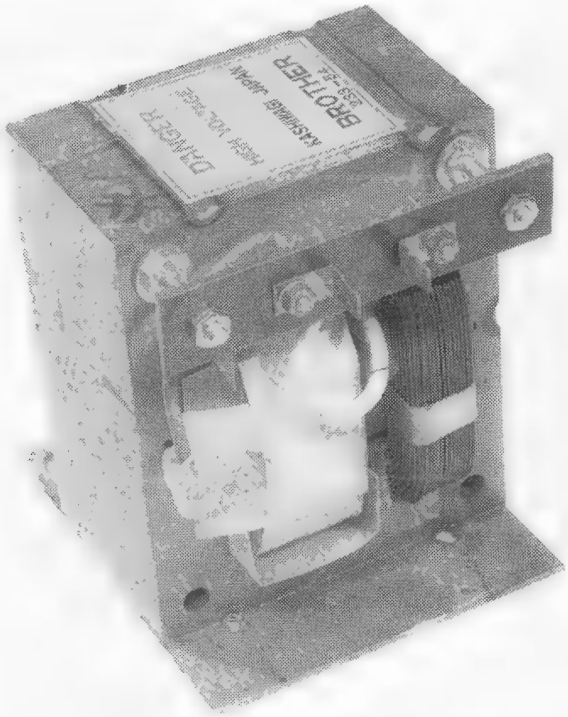

Photo 4 - Terminal strip fitted.

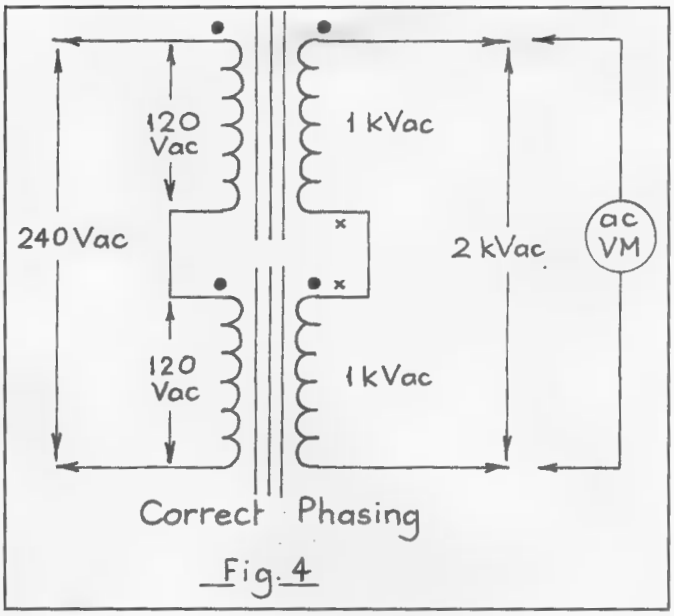

Fig. 4

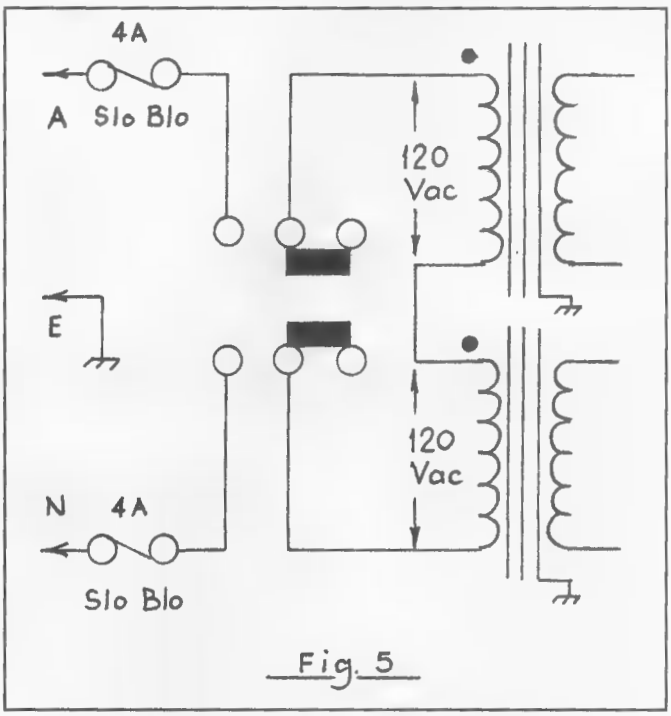

Fig. 5

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References and Further Reading

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